2. SYSTEM DESIGN

During the preparation of the VA (DOE 1998b), the DOE directed the Management and Operating Contractor (M&O) for the Civilian Radioactive Waste Management Program to conduct a formal study of alternative design concepts for a potential geologic repository for SNF and radioactive HLW at Yucca Mountain, Nevada (Dyer 1998). The study, called the License Application Design Selection project, was initiated in July 1998, and resulted in the development and submission of the report in April 1999 and Revision 1 in May 1999 (CRWMS M&O 1999c). The focus of this study was on the engineered aspects of a potential repository that would complement the natural system of the Yucca Mountain site. The final study report evaluated five EDAs that addressed a range of thermal management strategies and incorporated many design features evaluated in the initial stages of the study. The LADS addresses comments by the Nuclear Waste Technical Review Board (NWTRB) to study alternatives to the repository reference design (Cohon, J.L. 1998). The selected alternative, EDA II, incorporates a lower thermal load than was assumed for VA. This design alternative addresses NWTRB concerns about the modeling of coupled process in calculating repository performance.

For the vast majority of the radionuclides that would potentially be emplaced in a repository, the Yucca Mountain site alone (the natural barrier system) appears to be capable of containing them and preventing any transport to the accessible environment. A small fraction of the radionuclides appear to be mobile and, under some circumstances, could move out of the potential repository if they are exposed to water. This concern can be mitigated by use of an engineered barrier system to limit the exposure of these radionuclides to the small amount of water moving through the unsaturated zone at the site. A major focus of the repository design process is to identify a sufficient set of engineered barriers to accomplish this task.

Since the LADS recommendation is a conceptual design, the various design elements considered during the study were conceptual in nature. More detailed design activities will occur following the LADS project and prior to the possible SR and LA. By keeping the evaluations at a conceptual design level, the LADS team considered a wide range of design options, despite the differences in data available for various design elements.

2.1 SCOPE

The selected repository concept can be characterized as a low thermal impact design. This design uses more extensive thermal management techniques than the VA design to limit the impacts of the heat released by the waste. These thermal management techniques include thermal blending of SNF assemblies, closer spacing of the waste packages, wider spacing of the waste emplacement tunnels (drifts), and preclosure ventilation. Thermal blending of SNF assemblies reduces the peak heat output of the waste packages, making it easier to limit temperatures in the rock around the waste packages. Closer spacing of the waste packages in the emplacement drifts reduces temperature variations in the drifts, simplifies the analysis of the effects of heat, and reduces the total length of the drifts excavated. Spacing the drifts further apart reduces the effects of the heat from each drift on its neighbors, leaves a wide region of rock between drifts, which stays below the boiling point of water so that water can move around the hot drifts and flow down through the cooler areas, and limits the long-term alterations to the repository rock caused by the heat from the waste. Preclosure ventilation makes it possible to stay within temperature limits in the rock and around the waste packages during operation despite the much closer waste package spacing. It also reduces maximum temperatures after closure by removing energy before closure that would otherwise heat the repository rock.

2.1.1 Basis for Recommendation

The selected design provides a good balance of the ability of lower temperature designs to reduce uncertainties regarding postclosure performance, flexibility, and cost.

2.1.2 Performance

Performance assessment models used for EDA II indicate that the selected design would perform extremely well with respect to a screening criterion of 25 millirem/year to an average member of a critical group living 20 kilometers from the potential repository during the first 10,000 years. A calculated dose rate of 25 millirem/year would not be reached for more than 300,000 years, and the dose rate at any time would be less than 100 millirem/year. The calculated time of the first corrosion failure of a waste package is approximately 100,000 years.

2.1.3 Reduced Uncertainty

EDA II offers a number of advantages for the licensing safety case compared with designs with greater thermal effects. First, it reduces or avoids uncertainties associated with the thermal pulse when large quantities of water could possibly pool above the repository, and then subsequently flow into the drifts where the water could corrode the hot drip shields or waste packages. Second, by allowing only a small amount of the rock mass several meters around the drifts to exceed the boiling point of water for several hundred years, the design reduces the potential for long-term hydrological and geochemical alteration of the host rock. Third, the wide drift spacing reduces the analytical complexities resulting from temperature interactions among closely spaced drifts, simplifying the analysis of repository performance. Fourth, the design does not subject the Alloy-22 waste package material to temperature/humidity conditions conducive to aggressive crevice corrosion. As a result of both thermal conditions and the diversion of water by the drip shield, the Alloy-22 waste package material is subject only to very slow general corrosion.

2.1.4 Construction/Operations

The selected design achieves many of the operational benefits of other LADS designs and the VA design that have more extensive thermal effects in terms of the ability to use larger waste packages and reduce the length of emplacement drifts that must be excavated. EDA II provides operational flexibility by allowing cooler SNF and HLW to be placed into drifts separate from the hotter SNF. This avoids the need for careful staging and sequencing of the emplacement of waste packages containing DOE and commercial nuclear materials assumed in the VA design (DOE 1998b).

2.1.5 Technical and Programmatic Flexibility

The low thermal impact design allows focused progress toward a final design for a possible SR and LA, without precluding future revisions of major program goals or repository design attributes. Specifically, no additional technology development or site characterization would be needed to allow transition to lower temperature goals by extending the preclosure ventilation period. Although the selected design requires more area than the VA design, it still leaves room to accommodate 105,000 metric tons of waste (if such an increase in capacity were authorized) within an area that has already been characterized.

2.1.6 Confirmation and Retrieval

Activities to confirm that a repository is working as expected would begin long before the first waste is emplaced. In the current site characterization phase, information concerning Yucca Mountain and the surrounding environment is being collected and compiled to provide a baseline against which to compare what occurs after the repository is built and waste is emplaced. When repository operations begin, remote sensors will monitor the waste packages, emplacement drifts, and surrounding rock. The monitoring data will be compared to the baseline to determine the observed effects of the repository, and the observed effects will be compared to the model predictions. These confirmation activities will determine whether the repository is performing as expected and will continue until the repository is closed and sealed.

If a problem is detected prior to closing and backfilling the repository, remedial action or retrieval of the waste would be possible using remotely operated equipment. The NRC currently requires that the repository be designed to allow the retrieval of waste at any time up to 50 years after waste operations begin. Any retrieval of waste would follow, in reverse order, the same steps taken in emplacing the waste and, for the most part, would use the same systems and equipment. This cost estimate does not include costs for retrieval.

After the last package is placed underground, the repository could be monitored for many decades, perhaps even centuries. Permanently installed sensors would monitor waste packages, emplacement drifts, and the surrounding rock, providing the data required to confirm performance. A remotely operated inspection gantry would track conditions in the waste emplacement drifts.

2.1.7 Repository Closing

To provide future generations the option of closing the repository or monitoring it for long periods of time, the repository could be designed so it could be kept open from 50 to 300 years after the beginning of emplacement. This analysis addresses two scenarios that reflect the principal options being considered. Case 1 assumes closure 50 years after emplacement starts, as was assumed in the LADS Report (CRWMS M&O 1999c). Case 2 assumes extended ventilation for a total of 125 years after emplacement starts to reflect an approach to meet lower thermal goals.

Permanently closing the repository would require the sealing of all shafts, ramps, exploratory boreholes, and other underground openings. These actions would discourage any human intrusion into the repository and prevent water from entering and radionuclides from escaping through these openings.

At the surface, all radiological areas would be decontaminated, all structures taken down, and all site-generated wastes and debris disposed of at approved sites. The surface area would be restored as closely as possible to its original condition. Permanent monuments would be erected around the site to warn any future generations of the presence and nature of the buried wastes.

2.2 DESIGN DIFFERENCES BETWEEN THE VA AND EDA II

EDA II is compared with the VA design (DOE 1998b) in Table 3. EDA II uses more area than the VA design, but is capable of emplacing 70,000 MTHM within the upper emplacement level and more than 105,000 MTHM in the characterized area. Its wider drift spacing improves drainage and thermal independence of the drifts. Its steel ground support, invert and Alloy-22 waste package pedestal reduce performance uncertainties attributable to the effects of concrete on radionuclide mobilization and transport in the VA design. In EDA II, the waste package corrosion-resistant material, Alloy-22, protects the underlying structural material, stainless steel 316L, from corrosion. In contrast, the VA design had its structural material, carbon steel, covering the corrosion-resistant material, Alloy-22. One reason for the change was the possibility that the failure mode of the VA structural material may accelerate the failure of the corrosion-resistant material.

Table 3. Comparison of Enhanced Design Alternative II and Viability Assessment Design

Design Characteristics	EDA II Design	VA Design
Areal Mass Loading	60 MTHM/acre	85 MTHM/acre
Drift Spacing	81 m	28 m
Drift Diameter	5.5 m	5.5 m
Waste Package Spacing	Line loading: 10 cm	Point loading: Spacing varies (several meters)
Total Length of Emplacement Drifts	54 km	107 km
Ground Support	Steel	Concrete lining
Invert	Steel with sand or gravel ballast	Concrete
Number of Waste Packages[a]	10,039	10,500
Waste Package Materials	2-cm Alloy-22 over 5-cm stainless steel 316L	10-cm carbon steel over 2-cm Alloy-22
Maximum Waste Package Capacity	21 pressurized-water reactor (PWR) assemblies	21 PWR assemblies
Peak Waste Package Power to Average PWR Power (blending)	20% above average PWR package	95% above average PWR package
Drip Shield	2 cm Ti-7	None
Backfill	Yes	None
Preclosure period	50 years & 125 years	50 years
Preclosure ventilation rate	2 – 10 m^3/s	0.1 m^3/s
Performance (Central Estimate)[b] and Cost		
First/Median Drip Shield Failure	9,000/55,000 years	N/A
First/Median Waste Package Failure	100,000/325,000 years	4,000/165,000 years
Performance Margin	103	103
Time to Reach 25 mrem/yr	305,000 years	150,000 years
Peak Dose Rate	85 mrem/yr	330 mrem/yr
Time of Peak Dose Rate	630,000 years	310,000 years

NOTES [a] These waste package counts represent the VA and LADS EDA scope of 70,000 MTU of waste only.

[b] These performance estimates do not represent a licensing case. They are preliminary calculations for conceptual designs.

The installation of drip shields and backfill in EDA II at closure will require reliable operation of remotely controlled equipment in a high-temperature environment with radiation. These tasks are not required in the VA design, although similar capability will be required to respond to off-normal events. The remote installation tasks are mitigated in EDA II by the preclosure ventilation, which limits preclosure drift temperatures to sub-boiling, compared to about 170°C for the VA design. Emplacement of waste packages is also different for the two designs. For the VA design, the waste packages would be emplaced using a gantry that lifts and carries the waste packages by their ends. Due to the smaller gaps between the EDA II waste packages, the waste packages would be emplaced by equipment lifting them from below, but which would back out of the drift after emplacing the pre-assembled waste package and support hardware.

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